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PUBLIC INVESTMENT AND AGRICULTURAL PRODUCTIVITY: A STATE-WISE ANALYSIS OF FOODGRAINS IN INDIA

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PUBLIC INVESTMENT AND AGRICULTURAL PRODUCTIVITY: A STATE-WISE ANALYSIS OF FOODGRAINS IN INDIA

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ABSTRACT

The main objective of the study is to examine the long-run relationship between public investment and foodgrain productivity across the fifteen major states of India. The analysis is confined to the period, 1974-'75 to 2005-'06. In order to examine the long-run impact of public investment on foodgrain productivity, the study uses Koyck's Autoregressive Distributed Lag model (ADL). The study observes that the productivity levels are higher in those states where the initial investments were above the national average. The major conclusion of the study is the existence of a positive but lagged effect of public investment on productivity. The lag varies across states; as low as 0.5 years in Gujarat and as high as more than 10 years in Punjab, Haryana and Kerala. The existence of the lag, the study argues, might point to the need for sustained public investment as a means to raise foodgrain productivity in the future.

Keywords: Public Investment, foodgrains, productivity

JEL Classification: Q1, Q14, Q15, Q16

"*Investment in agriculture is a necessary, if not sufficient, condition for increasing agricultural production and productivity and thereby to ensure the availability and accessibility of food to the population*" (FAO, 1999:2)

1. A Theoretical Backdrop

The role of the State as an agent in raising agricultural productivity began to be seriously discussed at the international level from the 1960s. These discussions emerged mostly in the context of the growth concerns of the newly emerging countries as well as in the context of the demographic pressures and food shortage of the Sixties. Technological revolution in agriculture, commonly known as 'the Green Revolution', gave further impetus to the enquiry into the role of investment, particularly of public investment, in raising agricultural productivity. Writing in 1964, Schultz noted that 'transforming traditional agriculture' warrants investment in physical and human capital. Productivity enhancement is the key to break away from traditional agriculture, the crucial feature of which is the low rate of return to investment that farmers have been using for generations. Significant opportunities for productivity growth in agriculture become available only through changes in technology – new husbandry techniques, better seed varieties, more efficient sources of power, and cheaper plant nutrients. Investment in such activities as agricultural research, leading to the supply of new inputs, and in the education of the farm people who are to use them, provide the basis for technical change and productivity growth in agriculture. Investment in these sectors, Schultz observes, is a matter of social goal, and the existence of spill-over effects necessitates public investments in most of them, especially in research and development, and education.

Taking the cue from Schultz, Hayami and Ruttan (1971) argued that a continuous stream of new technical knowledge and a flow of institutional inputs in which the new knowledge is embodied represent a necessary condition for modern agricultural development. According to them, this stream of new technical inputs must be complemented by investments in general education and in production education for farmers. They also considered an effective system of public research institutions, private agricultural supply firms and markets for factors and products as the critical elements of the growth process. In a similar vein, Nelson (1964) and Feder, et al. (1985) noted that public investment is necessary to promote technology adoption, stimulate complementary on-farm investment and input use and for marketing the agricultural goods produced. Antholt (1994) justified public investment in basic infrastructure, human capital formation and research and development as necessary conditions for private investment.

In the Indian context, a strong case for public investment in agriculture was made by Chakravarthy (1993). According to Chakravarty, the role of the State as an investor is envisaged neither in the simple Ricardian Model nor in the Marxian schemes of expanded reproduction. In India, the compulsions arising from the existing climatic and demographic characteristics require different types of investment including, in irrigation, fertilizers, better seeds, etc., and some of these capital inputs often require to be organised on a very large scale, which makes State intervention essential. Along with these yield-increasing investments, there is also the need for investment in infrastructure such as transport and electricity to enlarge the market and to provide suitable energy base for sustainable growth. Moreover, the inducement to invest on the part of private investors is significantly affected by the behavior of public investment. Therefore, Chakravarthy argued that transforming traditional agriculture means growing public investment involving a suitable mix of directly productive capital and social-overhead facilities.

One point that emerges from these studies is the necessity for public investment as a means to transform traditional agriculture and to raise agricultural productivity, though for different reasons. These reasons extend from the ‘market failure’ in providing certain important categories of investment due to externalities, to the complementarity of private investment with public investment. Certain items of investment like large-scale irrigation works involve heavy capital expenditure, which would be beyond the ability of the individual cultivator. Education of the farm people, research and development, transport, marketing facilities and electrification, to mention only a few, are indispensable items of investment to enhance productivity and requires direct governmental intervention. The present study is an attempt to explore the possible role that the Government investment has played in influencing the agricultural productivity over a long period of time in the Indian states.

1.1 Public Investment in Indian Agriculture: Empirical Evidence

Empirical works on agricultural investment in the Indian economy assumed greater importance since the late Eighties, most of them debating over the issue of complementarity between public and private investments. The issue arose in the context of the decline in public and private investments in the first half of the Eighties and the rise in private investment since the mid-Eighties despite the continued fall in public investment. This behavior of agricultural investment made researchers to investigate the true relationship between public and private investments, which were till then considered as complementary. Moreover, some of the studies also debated on the items to be included in the public investment series for analysing the trend in public investment and its relationship with private investment. Though all these studies emphasised on the role of public investment as a major factor in determining agricultural production and productivity, an in depth analysis of the long-run relationship between the two received very little attention.

Most of the studies were based on the data on agricultural investment provided by the National Accounts Statistics of the Central Statistical Organisation. Nevertheless, the investment series of the CSO was questioned by scholars like Chand (2000) and Gulati and Bathla (2001, 2002). Chand (2000) relied on the Finance Accounts of the states and Union Territories and constructed a new public investment series both at all India and state levels[1] to explore the relationship between public and private investment in agriculture. He also examined the effect of public investment on productivity. With the help of cross section multiple regression, the study observed a significant positive relationship between public investment and agricultural productivity across the states. Further, Chand refuted any complementarity between public and private investments.

Gulati and Bathla (2002) further redefined the public investment series given by Chand. They observed that public capital formation explained more than 90 per cent of the variation in private investment and also these two have significant impact on Agricultural Gross Domestic Product. According to them, public sector investments in canals and power do remain important for their inducement effect on private investment. They found that the growth rates of the real value of output of cereals and pulses decreased from 2.16 per cent per annum during the 1980s to 1.84 per cent per annum during the 1990s. The decline in the growth rate of cereals and pulses during the 1990s, to them, might be due to the fall in public investment during the 1980s. However, the period

1 A detailed discussion regarding the availability and comparability of data on public investment is given in section three.

selected by Gulati and Bathla for constructing the public investment series differed across states based on the availability of data. Also, they did not venture into state specific examination of the long-run relationship between public investment and productivity.

Roy and Pal (2002), in their study on investment, agricultural productivity and rural poverty, examined the relationship between investment and productivity for the period from 1965-'66 to 1998-'99 based on the Finance Accounts data. Using a simultaneous equation model the authors observed that both public and private investments have positive relationship with agricultural productivity. They also found that the effect of investment on productivity is stronger than the effect of subsidies.

The overview of the existing literature on public investment and agricultural productivity points to the fact that there are many factors that influence agricultural output and productivity growth. They include, credit, subsidy, rainfall, technology, modern farm inputs, private farm investments, public investments in human and physical capital, irrigation, extension services and also infrastructural facilities like rural roads, electrification and marketing facilities. However, most of these factors are in one way or the other related to public investment. Moreover, externalities in certain heads of investment like major and medium irrigation and infrastructure like roads and markets make public investment imperative. In the Indian context, investments on the part of private hands mostly depend upon the behaviour of public investment. Therefore, we may hypothesise that the agricultural productivity in India depends solely upon the acts of public investment. It is also worth hypothesizing that the public investment would take some time lag in imparting its effect on agricultural productivity. The duration of lag that public investment takes to influence the productivity may also vary across the states. There is hardly any study, which examines the long run impact of public investment on foodgrain productivity considering the lag effect.

Therefore, in the present study, we attempt to analyse the long-run relationship between public investment and foodgrain productivity across states and tries to trace out the average duration that the investment takes to influence foodgrain productivity.

The selection of foodgrains for our analysis is based on two reasons: one, almost 3/4th of the total irrigated area in India is used for foodgrain production; and two, more than 80 percent of the total public investment in agriculture is constituted by irrigation. The study is confined to fifteen major states and ten food crops. These states, taken together, constitute about 97 per cent of the total area under cultivation of foodgrains[2]. The period of analysis is from 1974-'75 to 2005-'06. The choice of the period is mainly on the consideration of availability of comparable data on state-wise public investment[3].

The study has been presented in five sections. Section 2 discusses the growth and interstate variation in foodgrain productivity. The third section deals with the growth and levels of public investment across the states. The impact of public investment on agricultural productivity is examined in the fourth section. The final section gives the major findings and conclusions of the study.

2. Growth of Foodgrains Productivity

The concept of productivity adopted here is the average yield per hectare of foodgrains. We examine the growth of productivity over the period from 1974-'75 to 2005-'06. Further we classify the whole period into six sub-periods based on five-year plan periods (from the Fifth to

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2 The other states have been excluded from the study because of two reasons - one, the time series data on area and production for these states are not available for all the years under analysis, and two, their contribution to the total food production in the country is negligible.

3 The data on state-wise public investment in a comparable classification is available only from 1974-'75 onwards. For more details on the methodology and availability of public investment see section three.

the Tenth Plan[4]). The annual plan periods, 1979-'80, 1990-'91 and 1991-'92, are included in their immediately preceding plan periods[5]. Thus we examine the plan-wise productivity for each of the sub-periods - 1974-'75 to 1979-'80, 1980-'81 to 1984-'85, 1985-'86 to 1991-'92, 1992-'93 to 1996-'97, 1997-'98 to 2001-'02 and 2002-03 to 2005-06. For computing growth rate of sub-periods, we use average of annual growth rates. The results are reported in Table 1 below.

As Table 1 shows, for the period from 1974-'75 to 2005-'06, Andhra Pradesh, Bihar, Haryana, Madhya Pradesh, Rajasthan, Uttar Pradesh and West Bengal register growth rates above the national level and all other states are having growth rates below the national average. For the whole period of analysis, Haryana shows the highest growth rate and Maharastra and Kerala registers lowest growth rates. The plan-wise analysis indicates that there is deceleration in the rate of growth of foodgrain productivity from the Eighth plan onwards at the national level after showing a higher growth rate during the Sixth Plan. Most of the states follow the same pattern of registering a higher growth rate either during the Sixth Plan or Seventh Plan and decelerating during the subsequent Plan periods. The only exceptions to this pattern are Gujarat, Karnataka, Maharastra, Orissa and Rajasthan. In these states, the rates of growth of productivity are significant in the later plan periods too.

An examination of the average levels of foodgrain productivity across the states shows that all the states are showing an increase in productivity levels from Fifth to the Tenth plan (Table 2). However, Karnataka and Tamil Nadu are the only states showing a decline in the absolute level of foodgrain productivity during the last plan period. An

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4 We consider only the first four years of Tenth Five Year Plan due to the availability of data.

5 That is, the year 1979-'80 is included in the Fifth Plan (1974-'75 to 1978-'79) and the years 1990-'91 and 1991-'92 are included in the Seventh Plan (1985-'86 to 1989-'90).

Table 1: Plan-wise Growth Rates of Foodgrain Productivity across the States

States	1974-'75 to 1979-'80	1980-'81 to 1984-'85	1985-'86 to 1991-'92	1992-'93 to 1996-'97	1997-'98 to 2001-'02	2002-'03 to 2005-06	1974-'75 to 2005-'06
Andhra Pradesh	3.6	2.2	4.5	3.7	2.7	4.0	2.8* (17.9)
Assam	-3.2	3.8	3.2	1.0	2.5	-0.3	1.6* (15.4)
Bihar	-3.6	9.1	1.2	7.3	2.1	-4.6	2.4* (10.6)
Gujarat	0.9	4.7	6.1	11.8	6.6	5.5	1.7* (3.9)
Haryana	3.6	5.6	6.7	2.5	2.1	-0.7	3.4* (19.8)
Karnataka	2.0	-0.7	3.9	2.7	-0.2	9.0	1.4* (5.4)
Kerala	1.5	1.3	1.7	0.0	2.3	1.2	1.3* (21.9)
Madhya Pradesh	-8.5	14.4	3.5	3.8	2.1	2.2	2.4* (9.6)
Maharashtra	3.2	-1.0	1.7	13.0	-1.2	2.6	1.2* (4.4)

cont'd...........

States	1974-'75 to 1979-'80	1980-'81 to 1984-'85	1985-'86 to 1991-'92	1992-'93 to 1996-'97	1997-'98 to 2001-'02	2002-'03 to 2005-06	1974-'75 to 2005-'06
Orissa	-6.1	12.0	5.6	-3.6	11.6	9.7	1.6* (4.7)
Punjab	5.3	3.9	2.3	1.8	1.4	-0.3	2.1* (16.6)
Rajasthan	-7.0	9.4	3.2	11.3	2.6	-2.2	2.3* (7.5)
Tamil Nadu	1.0	1.6	4.8	-0.5	3.2	-1.5	1.6* (5.6)
Uttar Pradesh	-3.9	13.0	3.2	3.3	0.9	-1.4	2.7* (14.2)
West Bengal	-1.2	7.7	4.4	1.1	2.6	0.5	2.8* (15.4)
India	-1.4	5.8	2.8	3.2	1.5	0.0	2.3* (20.2)

Note: 1. * Growth Rates are Statistically Significant at 1 per cent level
2. Figures in Parentheses are Corresponding t-values

Table 2: Plan-wise average levels of food grain productivity (output per hectare) across the States

States	1974-'75 to 1979-'80	1980-'81 to 1984-'85	1985-'86 to 1991-'92	1992-'93 to 1996-'97	1997-'98 to 2001-'02	2002-'03 to 2005-06
Andhra Pradesh	992	1227	1452	1746	1969	2040
Assam	943	1037	1124	1292	1386	1432
Bihar	898	978	1192	1406	1667	1516
Gujarat	901	1055	866	1169	1251	1444
Haryana	1316	1607	2040	2666	2931	3091
Karnataka	953	911	960	1212	1300	1194
Kerala	1498	1609	1745	1915	2016	2115
Madhya Pradesh	608	741	873	1056	1074	1124
Maharashtra	701	711	737	950	855	893
Orissa	770	875	993	1133	1132	1179
Punjab	2279	2760	3255	3627	3888	3954
Rajasthan	582	634	688	842	988	1008
Tamil Nadu	1421	1392	1820	2079	2335	1757
Uttar Pradesh	1036	1324	1621	1904	2086	2088
West Bengal	1257	1303	1739	2028	2244	2442
India	945	1080	1274	1522	1653	1669

important point to be noted is the case of seven states - Andhra Pradesh, Haryana, Kerala, Punjab, Tamil Nadu, Uttar Pradesh and West Bengal – which are having productivity levels above the national average for all the plan periods. All other states continues to be falling below the national average levels of productivity through out the plan periods except Bihar and Karnataka – while the former come in the above-average category during the Ninth plan and the latter during Fifth plan. This indicates the fact that the states, which had higher levels of initial productivity maintained their position throughout the period of analysis and the states, which had lower levels of initial productivity continued to be so.

3. Public Investment in Agriculture: A State-wise Analysis

Data Coverage

The major data source usually employed to analyse the trend in public and private investments in agriculture at the national level is the National Accounts Statistics (NAS) brought out by the Central Statistical Organisation (CSO). The NAS, however, does not give state-wise data on agricultural investment. Moreover, about 90 percent of the investment included in this series is constituted by investment on irrigation alone, with the exclusion of important heads of infrastructure investment like storage, rural roads and rural electrification (Rao, 1997; Chand, 2000). Identifying this lacuna, Chand (2000) constructed a new broad series of public investment based on the Finance Accounts of various States and Union Territories. Chand's series includes 23 heads of capital expenditure. But, the inclusion of all these heads in the series was questioned by Gulati and Bathla (2002). According to them, inclusion of the investments such as those in rural development, special area programmes and rural electrification in Chand's new series make the series suffer from either overestimation or underestimation. For instance, what is needed is the inclusion of investment in electricity 'that goes to agriculture' rather than rural electrification as such. They give three alternative concepts of public investment in agriculture. The first concept is the same as the conventional investment series given by the CSO. Under the second concept, they include investments under the concept one plus the amount of power supplied to agriculture each year. The third concept covers investments under concept two plus investments made in agriculture and allied activities as defined in the budgetary documents. These include capital expenditure on soil and water conservation, crop and animal husbandry, dairy development, plantations, storage and warehousing, agriculture research and education, co-operation, other agricultural programmes, fisheries, forestry and wildlife.

In the present study we follow the third concept employed by Gulati and Bathla, but with some modifications. We exclude 'power that goes to agriculture' due to the paucity of state-wise data. We also exclude expenditure heads like fisheries and forestry since these have, prima facie, no direct dent on agricultural productivity. Thus, the components of public investment included in the present study are crop and animal husbandry, soil and water conservation, dairy development, plantations, food storage and ware-housing, agriculture research and education, co-operation, rural development, other agricultural programmes and major and medium irrigation and flood control. Unlike other studies, we also include loans and advances made by state governments on crop husbandry and soil and water conservation in the public investment series. We restrict our analysis to the period from 1974-'75 to 2005-'06 because of the non-availability of comparable state-wise data on investment prior to the year 1974-'75 [6]. Since the data is available at current prices, we convert into a constant series at 1993-94 prices, using the deflator derived from the National Accounts Statistics[7]. Due to the difficulty in arriving at state-wise deflator on agricultural capital formation, the all India deflator has been used for all the states. In order to make allowance for

6 For details, see Chand (2000).

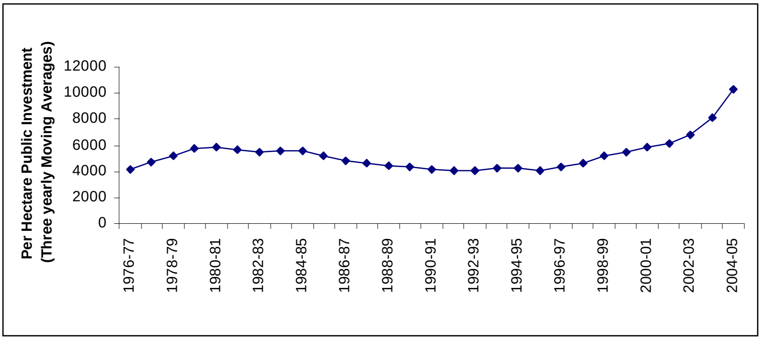
7 CSO gives time series data on public investment in agriculture at current as well as 1993-94 prices. We have derived the deflator from this data to convert our series into constant prices.

the importance of investment that each state has given to its agricultural sector, we consider the per hectare public investment, derived by dividing the investment figures by net sown area of each state.

Trend in Per Hectare Public Investment: All India

Figure 1 shows the three yearly moving average of per hectare public investment at the national level. We may observe three phases of public investment from 1974-75 to 2005-06: an increasing phase till the year 1980-’81, a steadily declining phase from 1981-’82 to 1995-’96 and a last phase of steep increase since the year 1996-97.

Figure: 1
Trend in Public Investment in Agriculture, 1974-75 to 2005-’06



We, therefore, estimate the state wise growth rates of public investment for these three periods separately using the kinked exponential growth model (Boyce, 1986). As shown in Table 3 from the mid seventies to 1980-’81, the growth rate of public investment at all India level had been significantly increasing at 7.2 percent per annum. The series shows a negative growth rate of –2.9 percent between 1981-82 and 1995-96, and about 10 percent rate of growth thereafter. In fact, the decline in public investment during the eighties has been observed by other studies on agricultural investment in India. According to Mitra (1996), the decline in public investment between 1980-’81 and 1990-’91 was 4.57 per cent

Table 3: Growth Rates of Public Investment across the States

States	1974-'75 to 1980-'81	1981-82 to 1995-'96	1996-'97 to 2005-'06
Andhra Pradesh	-0.32 (-0.09)	-1.6 (-1.5)	14.9* (8.3)
Assam	10.9** (2.6)	-5.7* (-4.8)	14.5* (6.8)
Bihar	15.7** (2.6)	-10.0* (-5.8)	13.1* (5.2)
Gujarat	11.8** (2.1)	-0.4 (-0.23)	3.9 (1.4)
Haryana	10.8 (1.5)	-9.7* (-4.5)	39.9* (5.4)
Karnataka	-1.6 (-0.27)	1.9 (1.1)	-7.5 (-1.3)
Kerala	8.2** (2.2)	-4.9* (-4.4)	-3.1 (-0.8)
Madhya Pradesh	6.3* (3.0)	-2.7* (-4.4)	-6.8* (-3.3)
Maharashtra	4.6 (1.6)	1.9** (2.2)	-0.2 (-0.02)
Orissa	19.9* (5.8)	-5.2* (-5.0)	9.6* (2.8)
Punjab	9.8 (0.9)	-0.6 (-0.2)	14.5 (1.4)
Rajasthan	0.9 (0.3)	0.7 (0.9)	-0.03 (-0.01)
Tamil Nadu	7.9 (1.5)	-11.7* (-7.7)	31.7* (6.2)
Uttar Pradesh	13.6* (3.4)	-7.6* (-6.4)	23.2* (5.7)
West Bengal	2.6 (0.9)	-6.6* (-7.9)	6.2** (2.2)
India	7.2* (6.1)	-2.9* (-8.4)	9.9* (8.4)

Note: 1. *, ** = Growth Rates are Statistically Significant at 1% and 5% respectively
2. Figures in parentheses are corresponding t-values.

per annum and even higher during the period 1986-'87 to 1992-'93. It implies that with respect to either the CSO series or the broad series that we have constructed, public investment had declined considerably during the eighties through mid nineties.

The all India pattern of the trend in public investment has also been observed for most of the states. Maharastra is the only state that shows a positive and significant growth rate during the second period. For all other states the rates of growth have been either significantly negative or zero. The decline during the eighties was more pronounced in Haryana, Tamil Nadu, Uttar Pradesh and Bihar. For the sub-periods 1974-'75 to 1980-'81 and 1996-'97 to 2005-'06, the growth rates of public investment in the majority of the states are positive and similar to all-India. However, the performance of each state in public investment and its interstate differences can be elucidated by looking into whether the higher growth rates are related to higher levels.

State-wise Average Levels of Public Investment

Table 4 shows that the all India average level of public investment increased from Fifth to Sixth plan and then declined during the subsequent two plan periods. During the Ninth and Tenth Plan periods, however, the amount increases to higher levels. The pattern is more or less similar for all the states except Maharastra, Kerala and West Bengal. In Kerala and West Bengal, the level of public investment has been continuously declining from the Sixth plan onwards. In the case of Maharastra, the investment level is fluctuating from Sixth to Tenth plan.

It can be noted that the states - Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Kerala, Orissa, Punjab, Tamil Nadu, Uttar Pradesh and West Bengal - had been ahead of the national average in per hectare public investment levels in one or the other of the initial two sub-periods (the Fifth and the Sixth plan periods). We may recall that in most of these states the rates of growth of foodgrain productivity too are observed

Table 4: Plan-wise Average Levels of Per Hectare Public Investment across States

States/Plan Periods	1974-'75 to 1979-'80	1980-'81 to 1984-'85	1985-'86 to 1991-'92	1992-'93 to 1996-'97	1997-'98 to 2001-'02	2002-'03 to 2005-06
Andhra Pradesh	**6106**	5258	**5116**	**5768**	**6703**	**17716**
Assam	**4975**	**6576**	**5583**	3393	4888	**12412**
Bihar	**7499**	**9792**	**8978**	3471	5518	8764
Gujarat	4244	**6693**	**4873**	**5395**	**7762**	7957
Haryana	**7187**	**8195**	4162	3083	**9987**	1275
Karnataka	**4765**	4723	3858	**5714**	**5575**	**14043**
Kerala	**10548**	**11445**	**6728**	**6424**	**5542**	4196
Madhya Pradesh	3287	3835	3792	2638	2248	6389
Maharashtra	4270	5462	**5043**	**6832**	**6800**	**13893**
Orissa	4388	**7158**	**5162**	3623	**5718**	4627
Punjab	**5319**	**7493**	**4660**	**5530**	**11608**	4822
Rajasthan	2280	2456	2149	2576	2795	3851
Tamil Nadu	4479	**7022**	2113	1598	3820	7092
Uttar Pradesh	**5052**	**6033**	4313	2762	**5690**	8198
West Bengal	**5951**	**6255**	3253	2741	2929	2545
India	4727	5700	4471	4100	5534	9366

Source: Computed from R.B.I Bulletin, various issues as higher than the national average. Therefore, it can be inferred that the better performance of these states in foodgrain productivity might have been due to the higher initial levels of per hectare public investment. However, this inference may be taken seriously only when we statistically prove it by considering the possible lag effect, which we discuss in the following section.

4. Public Investment and Foodgrain Productivity: A State-wise Analysis

The Methodology

There are a few evidences of the lagged effect of public investment and productivity at the national level. According to Rath (1989), the change in public investment during one plan will affect agricultural productivity during the next plan period. Gulati and Bathla (2002) view that investment in irrigation which constitutes a major part of public investment, might have a longer gestation lag - of about ten to twelve years - in influencing productivity. However, the gestation lags (although differently) between investment and productivity at all India level need not hold uniformly for all the states. Rather, it may vary across the states depending on the composition of public investment, crop composition, the response of private investment, soil conditions, climate and so on. Since there is no definite gestation lag that can be suggested for investment in influencing productivity in each state, we use the Autoregressive Distributed (Infinite) Lag Model (ADL model) given by Koyck (1954) to catch the lagged effect of investment on foodgrain productivity across the states.

Autoregressive Distributed Lag (ADL) Model

In regression analysis involving time series data, if the regression model includes not only the current but also the lagged (past) values of the explanatory variables, it is called a distributed lag model. If the model includes one or more lagged values of the dependent variable among its explanatory variables, it is called an autoregressive distributed lag model (Gujarati, 2003). There are two kinds of distributed lag models: the **infinite lag model** and the **finite lag model.** The length of the lag is not specified in the former, but is specified in the latter. Therefore, we consider the infinite lag model given as:

$$\mathbf{Y_t = \alpha + \beta_0 X_t + \beta_1 X_{t-1} + \ldots + u_t} \quad \ldots\ldots\ldots\ldots \quad \mathbf{(1)}$$

From the equation (1), Koyck has derived an ingenious method of estimating autoregressive distributed (infinite) lag model assuming that all the b coefficients decline geometrically as follows:

$$\beta_k = \beta_0 \lambda^k \qquad \mathbf{k = 0,1,} \quad \ldots\ldots\ldots\ldots \quad \mathbf{(2)}$$

where λ, such that $0<\lambda<1$, is known as the rate of decline, or decay. Koyck's autoregressive distributed lag model replaces all the lagged values of the explanatory variable with a single lagged value of the dependent variable, and therefore, his procedure is known as Koyck transformation[8] . The model can be written as:

$$\mathbf{Y_t = \alpha (1-\lambda) + \beta_0 X_t + \lambda Y_{t-1} + v_t} \quad \ldots\ldots\ldots\ldots \quad \mathbf{(3)}$$

where, $\mathbf{v_t = (u_t - \lambda u_{t-1})}$, and $\mathbf{(1-\lambda)}$ = the speed of adjustment. Therefore, higher the λ value lower will be the speed of adjustment.

Our analysis of the long run impact of public investment and foodgrain productivity across the states relies on this model given by equation (3). With this model we can compute the lag length of the explanatory factor ($\mathbf{X_t}$). Koyck has suggested two ways of computing the lag: one, median lag and the other mean lag, where,

Median lag = - log 2/log (λ) and Mean lag = λ / (1-λ)

The median and mean lags serve as a summary measure of the speed with which Y responds to X. These measures give the time that X takes to accomplish 50 per cent change in Y.

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8 For detailed discussion of the model see Gujarati (2003: Chapter 17)

It should be noted that the usual Durbin Watson d-statistic is not enough to check the autocorrelation of the explanatory factor with the stochastic error term. One alternative suggested is Durbin's ***h*** test. The method of computing h-statistic is:

$$\textbf{Durbin's } h = \rho \sqrt{\frac{n}{1 - n[\mathrm{var}(Y_{t-1})]}}$$

Where, $\rho \approx$ **1-(d/2), 'd'** is Durbin-Watson d-statistic, '**n**' is the number of observations and **var** $(\mathbf{Y_{t-1}})$ is variance of lagged $\mathbf{Y_t}$. However, the computation of the Durbin's h-statistic has its own limitations. If the term in the denominator of the square root becomes negative, then we may not be able to compute the statistic and also it tests only the first-order autocorrelation. Hence, for checking autocorrelation we also report the Lagrange Multiplier autoregression test for overall significance.

Unit Root Test

It has been observed that the conventional regression method for examining the relationship between two time series variables that are non-stationary will often lead to spurious regression (Harris, 1995)[9]. Most economic series are non-stationary and contain one or more unit roots. Therefore, in order to establish the true relationship between time series variables one must check for the non-stationarity or presence of unit roots in these variables (Granger and Newbold, 1974 and 1977). For that we can exercise the standard Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) unit root test. Accordingly, if the variable has no unit root, then they are stationary and if it has unit roots, then differencing the variable could make it stationary. Hence, we proceed with testing for the unit root in the case of foodgrain productivity series and the public investment series for each state and all India for the period from

9 Spurious regression means that the results obtained will suggest a statistically significant relationship between the variables in the regression model when in fact all that is obtained is evidence of contemporaneous correlation rather than meaningful causal relation.

1974-'75 to 2005-'06. The results of unit root tests are reported in Appendix 1, Tables A1 to A4.

As per the DF and ADF tests, the foodgrain productivity series of all India and 13 states do not have any unit root and therefore are integrated of order zero (**I(o)**)[10] . For the states Bihar, Karnataka and Tamil Nadu, the productivity series have unit root, but are stationary at first difference (integrated of order one – $I_{(1)}$). The DF and ADF tests for investment series shows that only five states – Gujarat, Haryana, Kerala, Punjab and West Bengal - have no unit root (integrated of order zero) and therefore are stationary. As noted above in all these states foodgrains productivity series also are stationary. The series for the other states, except Andhra Pradesh[11], are stationary at the first difference (that is, integrated of order one, $I_{(1)}$). Among these states, Bihar, Karnataka and Tamil Nadu have stationarity at its first difference in case of both foodgrain productivity and investment series. Hence, the regression analysis using the ADL model (equation 3) can be applied only for eight states: Bihar, Gujarat, Haryana, Karnataka, Kerala, Punjab, Tamil Nadu and West Bengal. All other states and all India are integrated of order zero (**I(o)**) in productivity series and of order one ($I_{(1)}$) in investment series. Hence, statistical analysis using time series technique cannot be applied to the relationship between investment and productivity in these states and for all India, since they might show spurious regression[12].

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10 It can be seen that without including any deterministic variables like trend or constant, none of the states is following stationary in productivity series. Some of the states are becoming stationary if we include constant, and all the states (except Bihar, Karnataka and Tamil Nadu) follow stationary only with the inclusion of constant and trend. Since most economic variables have a trend ingrained, we include a constant and trend in the model for unit root test. Hence, we consider the test of that model only.

11 For Andhra Pradesh and all India, the public investment series are not stationary upto the fifth difference.

12 However, it does not mean that there is no relationship between foodgrain productivity and public investment in these states. But the time series method that we use does not have the scope of estimating such a relationship in these states due to the existence of stationarity problem.

ADL Model Estimation

With respect to equation (3) we can re-write the model in order to examine the long-run relationship between public investment and productivity as:

$$\mathbf{P_t = \alpha\,(1\text{-}\lambda) + \beta_0\, I_t + \lambda P_{t\text{-}1} + v_t} \quad \text{..................................} \quad \mathbf{(4)}$$

where **P** is foodgrain productivity series of each state, **I** is the Investment series and $\mathbf{P_{t-1}}$ is the lagged value of productivity series, which gives the lagged effect of investment. The results are reported in Table 5.

Table 5 shows that the coefficient of current investment (b_0's) is significant only for Karnataka. That is, Karnataka is the only state in which the public investment is showing a contemporaneous relationship with foodgrain productivity. For all other states, there is no evidence of a one to one relationship between these two variables. Some of the states even show negative but, insignificant coefficients. As hypothesised, we may note that in all states (except Gujarat[13]) the coefficients for the lagged variables are highly significant[14], implying the presence of time lag that investment takes to accomplish its effect on productivity. Hence, our analysis extends the earlier hypothesis of lagged relationship between public investment and productivity put forth at the national level to the state level[15]. We also observe that the lagged coefficients of Haryana, Kerala and Punjab are relatively higher when compared to other states. This indicates that the speed of adjustment or the time that investment takes to accomplish its result on productivity for each state would be varying, which we examine in the next section.

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13 Though Gujarat shows a positive coefficient, it is not statistically significant.

14 The Durbin's h-statistics for all the states show that there is no autocorrelation problem in the explanatory variables at 5 per cent level. The residual properties are almost satisfied. The AR-1 statistic also shows that there is no residual autocorrelation in any of the states at 5 percent level except for Punjab and West Bengal.

15 See Rath (1989), Rao (1994) and Gulati and Bathla (2002).

Table 5. Results of the Relationship between Total Public Investment and Foodgrain Productivity

States	Constant	β_0	λ	Durbin's h-statistic	Residual Analysis					
					AR-1	ARCH	Normality	Xi ^ 2	Xi*Xj	RESET
Bihar	408.7** (2.2)	-1.5 (-1.3)	0.77* (7.4)	-1.4	1.9749 [0.1598]	0.64724 [0.4287]*	6.2486 [0.0440]	0.76143 [0.5615]	0.60788 [0.6948]	1.2425 [0.2752]
Gujarat	591.9* (3.1)	4.1 (1.6)	0.23 (1.02)	#	1.6398 [0.2142]	0.13574 [0.7157]	3.3719 [0.1853]	0.92289 [0.4685]	1.0803 [0.3997]	1.2237 [0.2788]
Haryana	186.2 (1.3)	0.03 (0.03)	0.94* (16.9)	-2	2.5517 [0.0981]	2.95e-005 [0.9957]	4.2162 [0.1215]	0.86826 [0.4985]	0.73132 [0.6080]	0.055784 [0.8151]
Karnataka	240.4 (1.6)	1.9* (2.6)	0.68* (4.7)	-0.2	0.60773 [0.5524]	0.17011 [0.6835]	3.2737 [0.1946]	0.68354 [0.6109]	0.87598 [0.5140]	3.5396 [0.0712]
Kerala	101.9 (0.5)	-0.14 (-0.2)	0.96* (10.3)	0.015	1.4846 [0.2459]	0.79662 [0.3806]	0.16726 [0.9198]	0.55191 [0.6997]	0.74195 [0.6007]	0.35838 [0.5546]
Punjab	328.1** (2.1)	-0.1 (-0.3)	0.92* (19.5)	-2.7	6.7990 [0.0044]**	0.37977 [0.5433]	0.62071 [0.7332]	4.5635 [0.0078]**	3.5267 [0.0180]*	0.64012 [0.4309]
Tamil Nadu	441.5 (1.8)	-0.6 (-0.4)	0.78* (6.6)	-0.3	0.28156 [0.7570]	0.47485 [0.4971]	3.2737 [0.1946]	3.4321 [0.0252]*	3.7274 [0.0143]*	1.1649 [0.2904]
West Bengal	563.5** (2.1)	-4.8 (-1.8)	0.81* (8.2)	-2.1	7.5908 [0.0027]**	0.082735 [0.7760]	1.1462 [0.5638]	3.2244 [.0317]*	2.4677 [0.0658]	3.3446 [0.0789]

Note:
1) * , ** = significant at 1% and 5% respectively.
2) # Durbin's h-statistic cannot be calculated for these states because of the denominator of the term inside the square root become zero.
3) For b_0 and l, figures in parentheses are corresponding t-values.
4) For Residual analysis,(AR-1 to RESET), figures in parentheses are corresponding P-values except for Normality – for that the figures in Parentheses are corresponding Chi ^ 2 values.
5) AR-1 is the Lagrange Multiplier Autoregression, ARCH is Autoregressive Conditional Heteroscedasticity, Xi ^ 2 and Xi*Xj are homoscedasiticity one and two and RESET is the Ramsey test for functional mis-specification in the model.
6) The null hypotheses of the residual analysis are: a) there is no autoregression (AR-1), b) there is no autoregressive conditional hetroscedasticity (ARCH), c) there is no heteroscedasticity (Xi ^ 2 and Xi*Xj), d) there is normality and e) there is no functional mis-specification.

After estimating the Autoregressive Distributed Lag model we have also tested for cointegration between investment and productivity for these eight states following Engle-Granger (EG) method. The need for this test is justified due to the fact that though the two series under consideration have same order of integration, it does not mean that there exists a long-run relationship between these two. As per the EG method, the residuals of equation (4)[16] have to follow zero order of integration in order establish the cointegration (or long-run relationship) between the two variables. Accordingly we have checked unit root for the residuals and the results are reported in Appendix 2. It shows that in all states the residuals are stationary **[$I_{(0)}$]** and therefore, the public investment in these states are having long-run relationship (cointegration) with foodgrain productivity. It can be noted that although in Gujarat there is no significant relationship (either contemporaneous or lagged) between investment and productivity with respect to the ADL model (equation.4), the cointegration test shows evidence for the existence of a long-run relationship in this state.

The Median and Mean Lags

We employ Median and Mean lag proposed by Koyck to examine the time that public investment takes to accomplish the changes in foodgrain productivity in each state. Since these two models are based on the λ coefficients of each state, one can expect that higher the λ value, lower will be the speed of adjustment.

Table 6 shows that the time lag between investment and foodgrain productivity varies across states. While in Gujarat it takes only less than a year to accomplish half of the effect of investment on productivity, in Bihar, Karnataka, Tamil Nadu and West Bengal it takes two to four years. The highest time lag has been observed for Haryana, Kerala and Punjab.

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16 The investment and productivity (equation. 4) follow I(1) for three states, and I(0) for five states. Therefore the residual should follw I(0) for statisfying the EG conditions of cointegration.

Table 6: Median and Mean Lag between Investment and Productivity

States	Lag length	
	Median Lag	Mean Lag
Bihar	2.7	3.5
Gujarat	0.5	0.3
Haryana	#	#
Karnataka	1.8	2.2
Kerala	#	#
Punjab	8.5	#
Tamil Nadu	2.8	3.5
West Bengal	3.3	4.3

Note: # = lag length is more than 10 years

We may observe that in these states, the public investment takes more than 10 years time duration to accomplish half of its influence on foodgrain productivity. The interstate differences in the gestation lag might be explained by the differentials in project implementation, composition of investment in irrigation (between major and minor projects), and delay in the use of complementary inputs besides soil characteristics and climatic conditions. We have not explored these aspects in the present study and needs further probe. Nevertheless, our observation of the positive and lagged impact of public investment highlights the need for sustained and secular increase in public investment so as to enhance the productivity and to ensure the availability of food in all the state of India.

5. Summary and Conclusions

This study aimed at examining the growth of foodgrain productivity and public investment and the long-run relationship between the two in fifteen major states in India for the period 1974-’75 to 2005-’06. In order to examine the long-run impact of public investment on foodgrains productivity, we used the Koyck’s Autoregressive Distributed Lag model (ADL). This model was applied to capture the gestation lag of the explanatory variable (public investment) in influencing the dependent factor (foodgrain productivity).

An interesting observation is that most of the states, which showed productivity levels above the national average during all the plan periods, were specifically those states which had public investment above the national average in the initial periods - either Fifth or the Sixth Plan. Given the lag between public investment and foodgrain productivity, it may be inferred that the better performance of these states in foodgrain productivity might have been due to the higher initial levels of per hectare public investment. However, some of these states fell below the national average level of per hectare public investment during the later Plans periods. Further, some other states, which had been having productivity levels below the national average, had investment levels higher than the national average during the last two plan periods. This would imply the possibility of these states showing better performance in foodgrain productivity in the near future.

The results of ADL model show that there is no contemporaneous effect of public investment on foodgrain productivity, but there exists significantly positive lagged effect for all the states. The lag had been longer in Haryana, Kerala and Punjab and shorter in Karnataka. The interstate variations in lag length that public investment takes to accomplish its result in productivity might be due to a number of state-specific characteristics, which we have not attempted to examine in the present study and needs further enquiry. We put forward the following hypotheses as the possible explanations for the interstate differences in lag length.

- The difference in gestation lag may be due to the difference in the composition of the total irrigation investment, that is, difference in the share of minor irrigation and major irrigation in each state. It might be possible that states with relatively larger share of minor irrigation may register quicker effect in productivity compared to others with relatively larger share of investment in major and medium irrigation. This is because of the fact that investments in major and medium irrigation will take more time in implementation compared to minor irrigation.

- The lag in the completion of public investment, especially irrigation, may cause private investment and other complementary inputs to come delayed, and hence the result of public investment on productivity might get delayed.
- It is possible that the interstate differences in the lag length between public investment and productivity might be due to the difference in the quality of the soil in each state. For states having better quality soil, a little bit of investment would be enough to show its impact on productivity in relatively lesser time compared to states with poor quality soil.
- Lastly, the issue of higher lag in highly productive states may be because of the fact that, once a threshold level or the biologically possible level of productivity[17] has been reached, the response to inputs would be slow. That means, the increase of yield for paddy from 2 tonnes per hectare to 3 tonnes per hectare may be faster than raising it from 4 tonnes per hectare to 5 tonnes.

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17 For example, the maximum biologically possible yield for HYV rice varieties is somewhere around 5 tonnes per hectare.

Appendix 1

Table A1: Unit Root Test for State-wise Productivity Series I(o)

States	t-ADF value (without constant and trend)	t-ADF value (constant included)	t-ADF value (constant and trend included)	Inference
Andhra Pradesh	1.6649 (8)	-0.0169 (8)	-5.0577** (0)	Stationary
Assam	2.4218 (8)	0.11924 (8)	-5.4418** (0)	Stationary
Bihar	-0.0107 (8)	-1.5674 (8)	-2.283 (8)	Difference Stationary
Gujarat	1.4177 (8)	0.56694 (8)	-4.6839** (0)	Stationary
Haryana	1.2264 (8)	-0.9015 (8)	-3.6491* (0)	Stationary
Karnataka	0.70479 (8)	-0.974 (8)	-2.3731 (8)	Difference Stationary
Kerala	2.6359 (8)	0.0513 (8)	-4.2671* (3)	Stationary
Madhya Pradesh	1.0782 (8)	-1.4477 (8)	-6.5607** (0)	Stationary
Maharashtra	0.70912 (8)	-3.5344* (0)	-4.3720* (0)	Stationary
Orissa	0.94518 (8)	-3.7970** (0)	-5.8711** (0)	Stationary
Punjab	0.64024 (8)	-3.0719* (6)	-4.2924* (0)	Stationary
Rajasthan	1.1019 (8)	-0.2033 (8)	-5.8474** (0)	Stationary
Tamil Nadu	-0.3699 (8)	-2.3351 (8)	-0.2937 (8)	Difference Stationary
Uttar Pradesh	-0.767 (8)	-1.4887 (8)	-3.7622* (0)	Stationary
West Bengal	1.1582 (8)	-3.3440* (8)	-4.7364** (4)	Stationary
India	-0.3722 (8)	-1.8995 (8)	-4.4936** (0)	Stationary

Note: 1. Figures in parentheses denote the optimum number of lags used.
2.* & ** = Significant at 5 and 1 per cent levels respectively.

Table A2: Unit Root Test for State-wise Productivity Series I(1)

States	t-ADF value (without constant and trend)	Inference
Bihar	-7.1364** (0)	Stationary
Karnataka	-5.8827** (0)	Stationary
Tamil Nadu	-6.0546** (0)	Stationary

Note: 1. Figures in parentheses denote the optimum number of lags used.
2.** = Significant 1 per cent levels

Table A3
Unit Root Test for State-wise Total Public Investment Series

States	t-ADF value without constant and trend)	t-ADF value (constant included)	t-ADF value (constant and trend included)	Inference
Andhra Pradesh	0.79273 (8)	2.3485 (8)	2.482 (8)	Difference Stationary
Assam	0.82643 (8)	-1.4052 (8)	0.27878 (8)	Difference Stationary
Bihar	-0.74858 (8)	-1.7324 (8)	-2.1223 (8)	Difference Stationary
Gujarat	0.49328 (8)	-0.06533 (8)	-3.9187* (2)	Stationary
Haryana	-2.0541* (0)	-3.6786** (0)	-2.2907 (8)	Stationary
Karnataka	1.9956 (8)	3.1479 (8)	1.6502 (8)	Difference Stationary
Kerala	-2.3058* (0)	-3.1837* (0)	-5.8371** (5)	Stationary
Madhya Pradesh	0.15973 (8)	-2.3272 (8)	-0.96627 (8)	Difference Stationary
Maharashtra	1.4995 (8)	2.2203 (8)	1.8602 (8)	Difference Stationary
Orissa	-0.83852 (8)	-1.5177 (8)	-1.6527 (8)	Difference Stationary
Punjab	-2.734** (0)	-5.864** (0)	-5.852** (0)	Stationary
Rajasthan	1.3984 (8)	1.3879 (8)	-0.22416 (8)	Difference Stationary
Tamil Nadu	0.14708 (8)	-1.0708 (8)	1.0269 (8)	Difference Stationary
Uttar Pradesh	0.58334 (8)	-2.4043 (8)	-2.2952 (8)	Difference Stationary
West Bengal	-1.9607* (2)	-4.3491** (0)	-3.9783* (0)	Stationary
India	1.1425 (8)	1.3584 (8)	1.6192 (8)	Difference Stationary

Note: 1. Figures in parentheses denote the optimum number of lags used.
2. * & ** = Significant at 5 and 1 per cent levels respectively.

Table A 4

Unit Root Test for State-wise Total Public Investment Series (First Difference (I(1))

States	t-ADF value (without constant and trend)	t-ADF value (constant included)	t-ADF value (constant and trend included)	Inference
Andhra Pradesh	4.167 (8)	4.091 (8)	3.356 (8)	@
Assam	-9.514** (0)	-9.769** (0)	-10.43** (0)	Stationary
Bihar	-6.227** (0)	-6.119** (0)	-5.985** (0)	Stationary
Karnataka	-7.961** (0)	-8.186** (0)	-8.730** (0)	Stationary
Madhya Pradesh	-4.834** (0)	-4.903** (0)	-5.058** (0)	Stationary
Maharashtra	-5.779** (0)	-6.033** (0)	-6.456** (0)	Stationary
Orissa	-4.988** (0)	-4.893** (0)	-4.989** (0)	Stationary
Rajasthan	-4.947** (0)	-5.039** (0)	-5.199** (0)	Stationary
Tamil Nadu	-3.625** (0)	-3.651* (0)	-3.934* (0)	Stationary
Uttar Pradesh	-9.250** (0)	-9.287** (0)	-9.306** (0)	Stationary
India	1.106 (8)	1.081 (8)	-0.7712 (8)	@

Note:
1. Figures in parentheses denote the optimum number of lags used.
2. * & ** = Significant at 5 and 1 levels per cent respectively.
3. @ = upto 5^{th} difference, the investment series of AP and India are not stationary

Appendix 2

Engle-Granger Test for Cointegration for Each State

Unit Root Test for Residuals (residuals of ADL regression)

BIHAR

ADF tests (Constant; 5%=-3.00 1%=-3.75)							
D-lag	t-adf	beta Y_1	sigma	t-DY_lag	t-prob	AIC	F-prob
3	-3.427*	-1.0431	160.1	0.6039	0.5534	10.34	0.7849
2	-3.792**	-0.84148	157.4	0.5492	0.5893	10.27	0.8406
1	-5.152**	-0.64316	154.6	1.606	0.1240	10.20	0.8861
0	-5.939**	-0.24769	160.3			10.24	0.7015

GUJARAT

ADF tests (Constant; 5%=-3.00 1%=-3.75)							
D-lag	t-adf	beta Y_1	sigm	at-DY_lag	t-prob	AIC	F-prob
0	-5.104**	-0.092256	256.5			11.18	0.7613

cont'd....

HARYANA

ADF tests (Constant; 5%=-3.00 1%=-3.75)							
D-lag	t-adf	beta Y_1	sigm	a t-DY_lag	t-prob	AIC	F-prob
1	-4.557**	-0.59017	188.0	1.043	0.3096	10.59	0.7874
0	-6.362**	-0.29426	188.3			10.56	0.7586

KARNATAKA

ADF tests (Constant; 5%=-3.00 1%=-3.75)							
D-lag	t-adf	beta Y_1	sigma	t-DY_lag	t-prob	AIC	F-prob
1	-3.704*	-0.15902	132.6	0.7464	0.4641	9.896	0.7740
0	-4.628**	0.0097723	131.2			9.837	0.8023

cont'd....

KERALA

ADF tests (Constant; 5%=-3.00 1%=-3.75)							
D-lag	t-adf	beta Y_1	sigma	t-DY_lag	t-prob	AIC	F-prob
1	-4.408**	-0.42543	62.60	1.621	0.1207	8.395	0.1676
0	-4.475**	-0.051060	64.98			8.431	0.1212

PUNJAB

ADF tests (Constant; 5%=-3.00 1%=-3.75)							
D-lag	t-adf	beta Y_1	sigma	t-DY_lag	t-prob	AIC	F-prob
3	-3.664*	-1.7486	140.4	1.180	0.2533	10.08	0.8082
2	-3.725*	-1.1899	141.9	0.6100	0.5491	10.07	0.7008
1	-5.109**	-0.91693	139.6	1.182	0.2512	9.999	0.7654
0	-8.200**	-0.53114	141.0			9.980	0.7058

cont'd....

TAMILNADU

ADF tests (Constant; 5%=-3.00 1%=-3.75)							
D-lag	t-adf	beta Y_1	sigma	t-DY_lag	t-prob	AIC	F-prob
3	-3.298*	-0.60883	225.2	0.7303	0.4746	11.02	0.1119
2	-3.590*	-0.39928	222.4	0.8301	0.4168	10.97	0.1562
1	-3.971**	-0.19658	220.6	0.8529	0.4038	10.91	0.1916
0	-5.025**	-0.0053690	219.2			10.86	0.2225

WEST BENGAL

ADF tests (Constant; 5%=-3.00 1%=-3.75)							
D-lag	t-adf	beta Y_1	sigma	t-DY_lag	t-prob	AIC	F-prob
3	-3.396*	-1.1924	112.1	0.6029	0.5541	9.628	0.3431
2	-3.882**	-0.95567	110.2	0.3334	0.7425	9.561	0.4404
1	-6.480**	-0.81763	107.7	2.373	0.0278	9.480	0.5553
0	-6.527**	-0.31067	119.0			9.641	0.2211

Note: *, ** = significant at 5% and 1% respectively

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